(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 August 2001 (09.08.2001)

PCT

(10) International Publication Number
WO 01/57398 A1

(51) International Patent Classification[7]: F03D 11/00, F16H 57/08, F03D 11/02

(21) International Application Number: PCT/IB01/00211

(22) International Filing Date: 31 January 2001 (31.01.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0002122.0 31 January 2000 (31.01.2000) GB

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/57398 A1

(54) Title: GEAR UNIT

(57) Abstract: A gear unit for wind turbine assembly, said gear unit comprising a planet gear stage wherein a planet gear is rotatably supported on a planet carrier by means of two bearings axially spaced relative to the axis of rotation of the planet gear, at least one of said bearings being a tapered bearing.

GEAR UNIT

The need for weight reduction in mechanical drives, for example in gear assemblies, and especially those used in wind turbines, has in the past lead to an increased use of planetary gear units.

In a number of applications, more and more lightweight design features are being introduced. The gear transmission of a wind turbine is an application for which a lightweight design is particularly beneficial because reduction in weight of the gear unit mounted at the top of a tower allows a reduction in the strength requirement of the tower.

The planet gear construction, such as shown by Figure 1, has to strive for an appropriate compromise between conflicting requirements such as:-

a. rim thickness of each planet gear, which is important both in respect of strength and stiffness, and affects both the gear and the bearing performance

b. bearing inner ring internal diameter, which determines the strength and the deflection of the planet carrier studs

c. bearing size and section, with its major effect on bearing life and guiding of the planet gear contact.

In this difficult compromise, relatively thin planet gear rim thicknesses are often used in state-of-the-art planetary stages. However, under some circumstances, the bearing outer ring can as a consequence be found to spin or creep relative to the planet gear. To prevent or inhibit any such movement and to minimise long term wear and fretting corrosion requires careful design and surface conditioning of the planet gear-to-bearing interface.

A particular feature of a gear transmission assembly used in a wind turbine is that it is subjected to a large variation in applied forces due to often rapidly varying winds loads acting on the wind turbine rotors, especially during turbulent wind conditions. The large variation in applied forces causes significant elastic deformation of gear unit components, including the planet and outer bearing ring assembly. This leads to a significant risk of creep of the bearing outer rings.

In some cases, state-of-the-art gear units have integrated the bearing partially with the planet gear. Because of the relatively lower contact pressures and the simple cylindrical raceway topography, this has been a successful approach for integration of outer rings of cylindrical or needle bearings with the planet gear, as seen in the example given in Figure 2a in which the planet gears 20 each serve also as a bearing outer ring contacted by the bearing rollers 21. Thus not only a different balance in the above design requirements could be achieved, also the creeping and spinning were eliminated. However, this construction also has disadvantages if adopted for a wind turbine.

Another prior proposal comprises the aforedescribed integration feature of Figure 2a with provision of a central, integrated planet gear section 25 (see Figure 2b) that extends radially inwardly between the axially spaced bearings 26. In this proposal special care is need to avoid undesirable stress concentration points. In some cases stress relieving notches 27 are provided in corner regions but there remains a potential risk of stress and fatigue probles

The present invention seeks to provide a gear unit for a wind turbine, a wind turbine gear transmission assembly and a wind turbine assembly in which further improvements are attainable.

In accordance with the present invention there is provided a gear unit for a wind turbine transmission assembly, said gear unit comprising a planet gear stage wherein a planet gear is rotatably supported on a planet carrier by means of two bearings axial spaced relative to the axis of rotation of the planet gear, at least one of said bearings being a tapered bearing.

Preferably the planet gear stage comprises a plurality of planet gears at least some and more preferably all of which are helical gears.

The outer ring (cup) of the, or each, tapered bearing preferably is integrated with the planet gear. That is, preferably a surface of the planet gear acts as the outer ring of a tapered bearing, for direct contact by the tapered rollers of the bearing.

A surface region of the planet gear may be specially treated whereby it is adapted to act as an outer bearing ring (cup).

Preferably each of the said two bearings is a tapered bearing. The axis of rotation of the rollers of the, or each, tapered bearing preferably are inclined such that they intersect the axis of rotation of the plant gear either at a position between the axially spaced bearings or at a position axially beyond the other bearing of the pair.

The invention provides also a wind turbine transmission assembly and a wind turbine which comprises a gear unit in accordance with the present invention.

One embodiment of the present invention will now be described, by way of example only, with reference to Figure 3 which, in common with Figgures 1 and 2, shows part of a gear unit in section in a plane containing the axis of rotation of a planet gear carrier.

A planet gear carrier stud 30 of the epicyclic gear unit of a wind turbine transmission assembly supports the inner bearing rings 31 of a pair of axially spaced taper roller bearings 32. The bearings 32 provide radial and axial support for a planet gear 33 the radially outer section 34 of which is provided with helically extending gear teeth to engage a ring gear.

The radially inner surface 35 of the planet gear 33 comprises two frusto-conical bearing surface zones 36 and a central zone 37 which in this embodiment extends radially inwards of the bearing rollers 38 to a position close to but spaced from the outer surface of the stud 30. In case the zones do intersect zone 37 can be reduced to zero.

The bearing rollers 38 directly contact the frusto conical surface zones 36 of the planet gear. Thus the planet gear may be considered as integrated with the outer rings of two tapered roller bearings. The bearings also are orientated such that in each bearing 32 the rollers reduce in diameter in a direction towards the other bearing of the pair. In this embodiment the axis of rotation X of each bearing roller 38 is inclined to intersect the axis Y of rotation of the planet gear at a position beyond the other bearing of the pair.

The planet carrier stud 30 is provided with a radially outwardly extending abutment (not shown) to provide for axial location of one of the bearings and the other bearing is axially located by an adjustable ring stop

(not shown) mounted on the stud 30 and of a kind known per se thereby to allow accurate setting of the bearing pre-load.

Figure 3 shows only a single planet gear 33 but the carrier for carrier stud (30) is provided with at least three studs each having mounted thereon a planet gear and pair of bearings corresponding to those illustrated.

In consequence of the provision of tapered roller bearings in a gear unit having helical type planet gears it is found possible to attain at least some of the following advantages, namely: -

- the contact pressure of the individual roller contacts is better distributed than in prior art constructions because of the inclined direction of loading (compare lines A and A' in Figure 2a and Figure 3) which increases the amount of material available (compare lengths C and C' in Figures 2a and 3) for distributing the load in the interaction with the loads coming from the gears
- increased working distance (B and B' in Figures 2a and 3) because of the inclined working lines A' in O-arrangement of the two tapered bearing results in better stability, for instance versus moments created by the presence of axial forces inherent in the use of helical gears.
- maximum mass (bulk) and stability of the rim section is achieved with no or minimal local stress relieving notches, as exemplified in comparison of Figures 2a, b and Figure 3
- the clearance of the bearing arrangement can be set (Figure 3) for optimal guiding of the gear contact and load distribution in the bearings
- setting of minimal clearance or even preload, together with increased stiffness leads to a high level of precision in positioning of the output shaft both under no load and under load conditions, which can be very important in wind turbine applications.

Figure 4 illustrates a wind turbine 40 comprising a gear box 41 that acts as a transmission assembly to transmit torque from the rotor blades 42 to a generator 43, the gear box 41 comprising an epicyclic gear unit having a planet gear stage as aforedescribed with reference to Figure3.

CLAIMS

1. A gear unit for wind turbine assembly, said gear unit comprising a planet gear stage wherein a planet gear is rotatably supported on a planet carrier by means of two bearings axially spaced relative to the axis of rotation of the planet gear, at least one of said bearings being a tapered bearing.

2. A gear unit according to claim 1 and comprising a plurality of planet gears at least some of which are helical gears.

3. A gear unit according to claim 2 wherein each said planet gear is a helical gear.

4. A gear unit according to anyone of the preceding claims wherein the planet gear comprises at least one surface region for contact by rollers of a tapered bearing.

5. A gear unit according to claim 4 wherein each of said two bearings is a tapered roller bearing and the planet gear comprises a pair of axially spaced frusto conical surfaces respectively for contact by bearing rollers of said two bearings.

6. A gear unit according to any one of the preceding claims wherein the axis of rotation of the rollers of the or each tapered bearing are inclined to intersect the axis of rotation of the planet gear at a position between the axially spaced bearings or at a position axially beyond the other bearing of the pair.

7. A gear unit according to any one of the preceding claims wherein the planet gear comprises a central zone which extends radially inwards of the bearing rollers of the or each tapered bearing.

8. A gear unit according to any one of the preceding claims wherein the planet carrier comprises adjustable bearing location means for adjustment of the bearing clearance or preload of the or each tapered bearing.

9. A gear unit for a wind turbine transmission assembly substantially as here in before described with reference to Figure 3.

10. A wind turbine transmission assembly comprising a ring gear, a sun gear, and a planet gear stage according to any one of the preceding claims for transmission of torque between said ring gear and sun gear.

11. A wind turbine comprising rotor blades connected to a wind turbine transmission assembly according to claim 10.

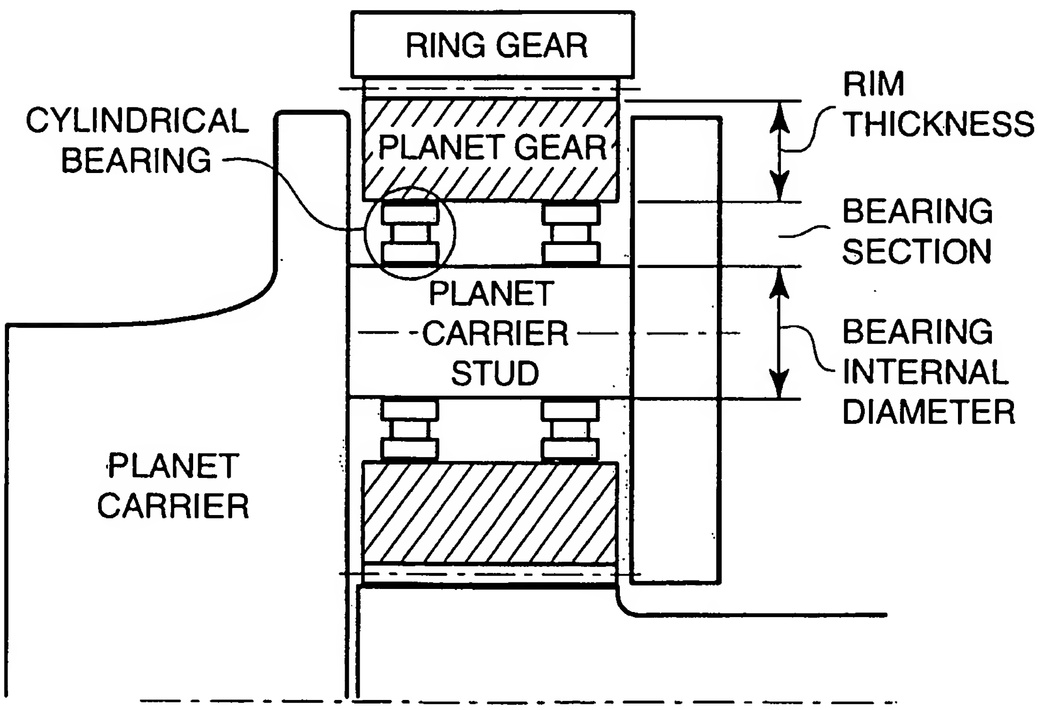
RING GEAR
RIM THICKNESS
CYLINDRICAL BEARING
PLANET GEAR
BEARING SECTION
PLANET CARRIER STUD
BEARING INTERNAL DIAMETER
PLANET CARRIER

FIG. 1

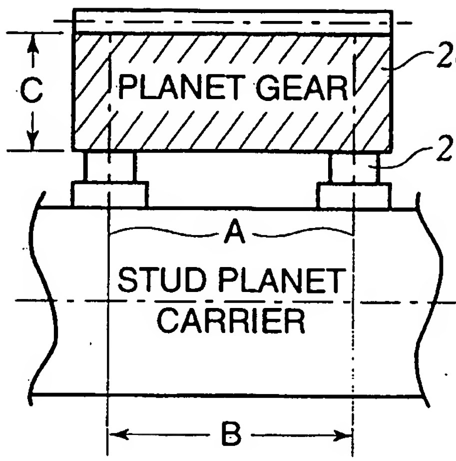

FIG. 2a

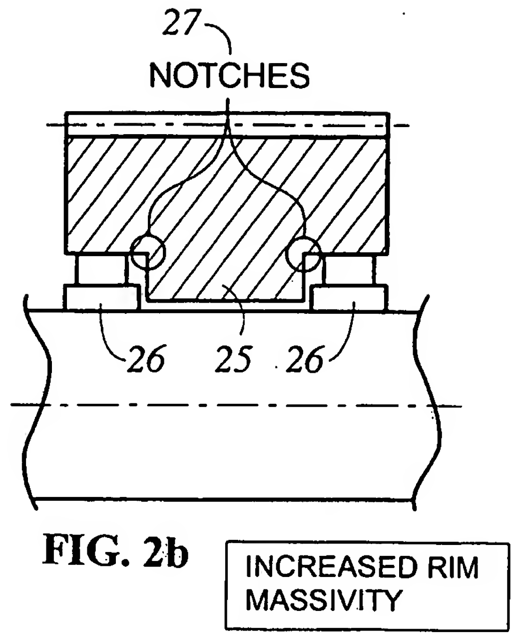

FIG. 2b

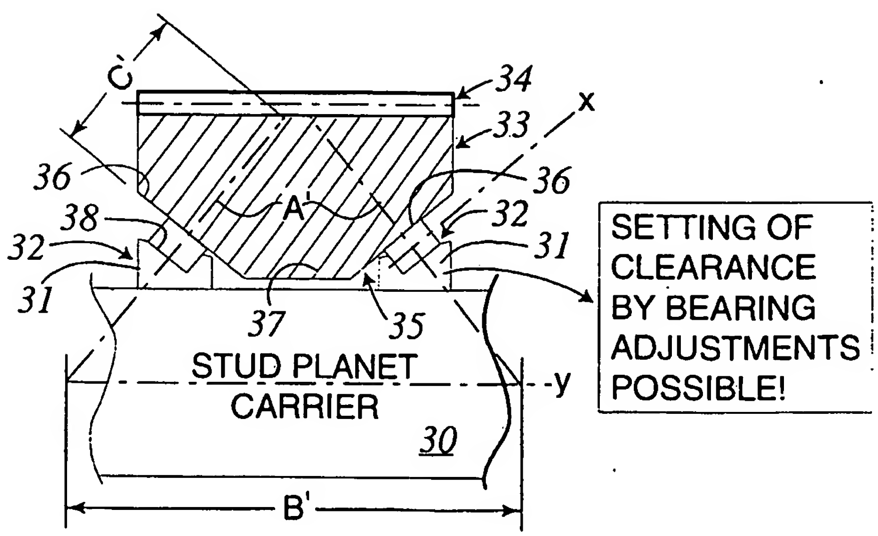

FIG. 3

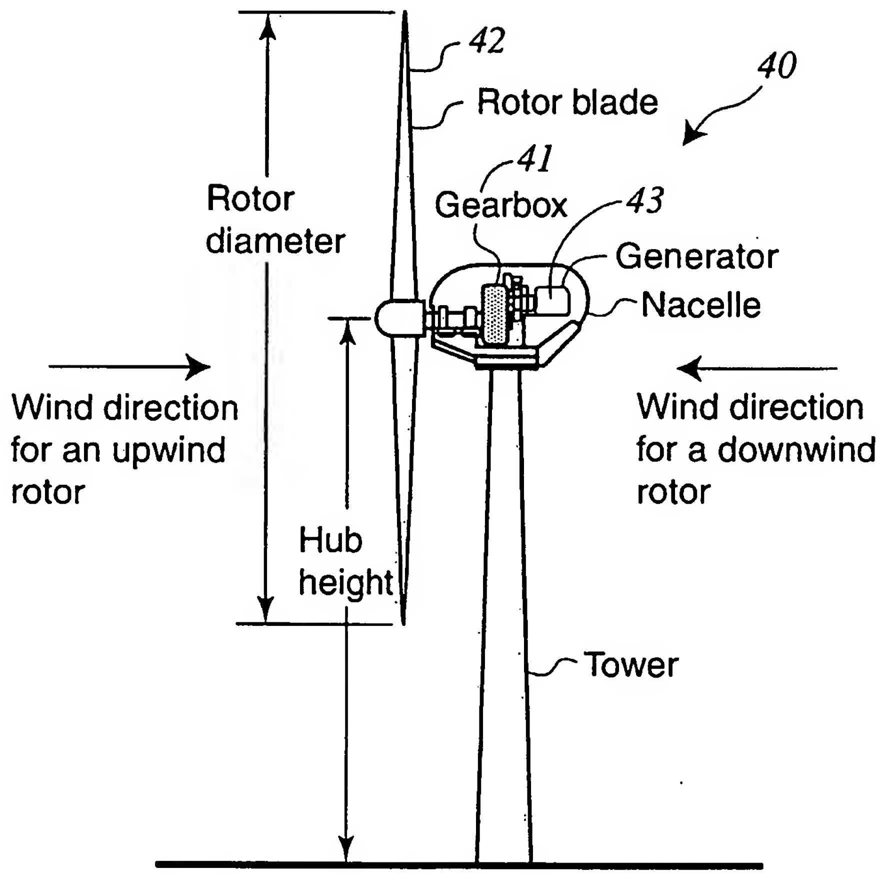
42
40
Rotor blade
41
Gearbox
43
Rotor
diameter
Generator
Nacelle
Wind direction
for an upwind
rotor
Wind direction
for a downwind
rotor
Hub
height
Tower

FIG. 4

INTERNATIONAL SEARCH REPORT

Intern Application No
PCT/IB 01/00211

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03D11/00 F16H57/08 F03D11/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16C F03D F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 876 181 A (SHIN CHAN) 2 March 1999 (1999-03-02) figures 2,5 -----	1,4-7, 9-11

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 July 2001	11/07/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern Application No
PCT/IB 01/00211

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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